# Features of Material Flow Accounting for the Efficient Supply Chain Management

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***Abstract*-Material flow accounting in supply chain management is a complex process for enterprises, regardless of industry and activities. Its use will enable companies to identify inefficiencies in the use of resources, as well as to assess the assets in terms of their durability, functionality, usefulness. Enterprises face many challenges in material flow accounting, and one of them is material flow accounting of stocks in the supply chain management. The organization has material losses in the absence of a coherent system of material flow accounting. The purpose of this study is to study the features of material flow accounting for the efficient supply chain management, to determine the effective systems of material flow accounting. We propose to use the MFCA system to account for material flow. It can be used to estimate material losses in the supply chain in terms of money and determine the economic benefits of resource efficiency. The MFCA methodology is regulated by the ISO standard. The article describes the process of material flow accounting at the studied enterprise in a specific example. It explains how to construct a methodological accounting framework to estimate resource losses from the economic point of view. We have systematized information on automated systems and programs for material flow accounting for the efficient supply chain management. A model of material flow accounting in accordance with ISO 14051 is developed and proposed for Alliance Oil Company. It is found that the production of gasoline produces a significant amount of by-products and waste. Only by-products, which are about 36 percent, are recorded under normal accounting. However, the use of MFCA has shown that most of the costs associated with material losses due to recycling products, waste, etc. In the study, we have compiled the matrix of material flow to Alliance Oil Company and found that the costs can be upgraded to material losses. In this case, they are $3930. $1130 is the estimated cost of electricity and the system cost of the refinery.**

**Keywords-** *material flow accounting; supply chain management; resource efficiency; MFCA; ISO 14051.*

## 1. Introduction

Studying and taking into account the material flow in the supply chains, it can be noted that a significant proportion of them is generated in production. Some scholars [1] believe that, first of all, it is necessary to take care of production accounting. However, material losses in production mean unproductive and huge costs in the supply chain. The standard ISO 14.040 plays an important role in material flow accounting for the efficient supply chain management [2]. It promotes the recording of the material flow cost. The standard also defines how to take stocks into account as an element of material flow for the efficient supply chain management. Previously, in management systems, the issues of accounting of material flow and energy resources are considered as a common goal of economic interests. Initial approaches that take into account the material flow cost are arranged in the accounting [3,4]. Accounting of the material flow helps to quantify all material and energy flows of the entire supply chain in a particular production system, linking them to the existing cost accounting. In addition, "a residual material cost accounting" is developed. It has adopted a similar approach and aimed to account for the costs (accumulated materials/goods) involved in the supply chain. In addition to the actual storage costs, inventory costs also include the material cost obtained from the raw material price, the cost of value-added component that has accumulated in the materials, the storage cost, processing of material residues [5]. In 1969 [4], the first version of the methodology was presented. In the 1990s, it was called the analysis of material flows of the national economy. Their main argument was that the economy is largely based on the accounting of all costs, even environmental costs, such as air and water, which becomes less and this excludes the optimal distribution. Unlike traditional approaches to material flow accounting,

in this study [6], it is proposed to account material costs on the basis of quantitative structure with transfer to the money equivalent (in dollars or Euros). Both approaches also transfer the cost component to the residue of the production system and, therefore, identify inventory costs as an additional cost unit [7].

These methodologies have been implemented in many pilot projects in Germany, for example, in Iba Geigy Pharma-Deutschland GmbH, ITT Automotive GmbH, and Merckle-Ratiopharm Group and tested in practice of these companies [8]. In Japan, this method was first used in 2000 and soon became widely used in the material flow accounting of supply chains. Ministry of Trade and Industry of Japan even funded the first studies in this direction and recommended the use of material flow accounting for the efficient supply chain management [9]. In 2007, Japan proposed to develop the MFCA standards in ISO 14000. The aim was to establish and standardize the general principles and framework of material flow accounting to provide a more widespread method and contribute to more efficient resource management in companies. In particular, the representatives or consultants of small and medium-sized companies were introduced to the MFCA methodology, and they implemented it in their enterprises through the simplicity of its basic concepts and scalability [10]. Material flows of supply chains were recorded, but only the direct costs were accounted for. This means, for example, that depreciation has not been taken into account, and the residual value of fixed assets has not decreased. Some researchers argue that waste disposal costs should be accounted only to material losses [11]. MFCA is one of the most popular methods of material flow accounting, which many scientists recommend to use. It is a system of accounting of material and energy flows, which can be used in management accounting of supply chain management. In this case, the material and energy flows are focused on cost accounting. The reasons for this are that the supply chain management and its material flows are directly related to the use of materials and energy, and in respect of industry and energy, material costs are the highest expenditure part of the company. Therefore, material and energy flows are very important, because their reduction is a common economic goal. The purpose of MFCA implementation is to increase resource efficiency in the material flow [12, 13]. In this way, losses and inefficient use of resources are displayed quantitatively and visualized in relation to their physical units and their cost. In this case, particularly the inefficient use, caused by production losses, gets the most attention in order to minimize. Since 2011, there is an international standard of management of material flow accounting - ISO 14051. It provides the framework, basic principles and initial steps for MFCA implementation [14]. More than 300 companies in Japan have launched this system and reported that it can be implemented with minimum effort and achieves good and quick results [15].

According to ISO 14051, there are four main MFCA elements: quantitative accounting centers, material balance, material flow model and cost accounting. The quantitative center may belong to a single process or to a group of several processes that are aggregated to the quantity center. In the quantitative center, the inputs and outputs are recorded in physical and monetary units. The material balance takes into account all inputs and outputs, entering and leaving the production supply chain system [16]. The ISO 14051 standard is a kind of addition to the ISO 14000 and offers a step-by-step guide to MFCA implementation with detailed calculation procedures. The material flow model, developed for MFCA, is also used as the basis for its possible extension to a supply chain life cycle model as a similar primary material, and material flow data is required for the design of supply life cycle delivery system [17]. Additional synergy for using the collected MFCA information is observed for the studied Alliance Oil Company in accordance with ISO/TS 14067 and oil accounting in accordance with ISO 14064 [18]. This synergy also allows us to use screening approaches for assessment of material flow accounting for losses. The cost savings is often the first desire of managers in MFCA implementation. The MFCA system helps organizations to recognize financial losses as "products" even if they are not sold. This indicates that production costs and material losses are calculated in the same way. For this purpose, the costs, caused by and/or associated with the material flow, entering and leaving the quantitative center, should be quantified and allocated to this material flow [11]. MFCA also helps to track the material flow and stocks of materials in the supply chain and within the organization in quantitative and physical units (for example, mass, volume), and the costs associated with this material flow are also taken into account. MFCA keeps a record of four types of costs: material costs, system costs, energy costs and waste

management costs. Each cost is determined as follows:

• Material cost: the cost of material that passes through the quantitative center. As a rule, the purchase price is used as the material cost.

• Energy cost: the cost of an energy source such as electricity, fuel, steam, heat, compressed air.

• System cost: the cost incurred in the internal processing of the material flow, excluding material costs, energy costs and waste management costs.

• Waste management cost: the cost of processing material losses [13].

It is necessary to take a number of implementation steps for MFCA implementation and material flow accounting for the efficient supply chain management. The level of detail and complexity of the analysis will depend on several factors such as the size of the organization, the nature of activities and products, the number of processes and quantitative centers selected for analysis.

The MFCA system can be implemented in organizations, regardless of the implementation of the system of organizational activities, but the implementation process is considered to be easier and faster in the context of an existing SEM, as environmental management data usually contain data related to materials and waste.

In addition, this system can provide important information at different stages of the Plan-Do-Check-Act (PDCA) supply chain and continuous improvement cycle. For example, the use of MFCA enables an organization to achieve financial indicators with goals and objectives. Knowledge of the potential environmental impacts and financial consequences can improve the quality of assessment, providing useful information for decision-making [12].

Each supply chain needs the support of the company's management for the effective management and successful completion. MFCA accounting is no exception. The company's management must understand the value and usability of this system. For material flow accounting, it is necessary to distribute roles and responsibilities, including the creation of a task force; providing resource; monitoring processes; review of the results; making decisions for improvements based on the MFCA results. Material flow accounting requires the following input data necessary for a successful implementation:

- Operational experience in the design, procurement, and production due to the material flow;
- Engineering and/or technical assessment of material consequences;
- Quality control assessment of various issues such as the rate of production, maintenance, and other quality control data;
- Environmental assessment of environmental aspects and impacts, types of waste and other environmental protection measures;
- Accounting assessment of cost accounting data, such as the cost of distribution of data and costs.

Studying supply chain management, it is also important to study the stocks of material flow, and understand how to integrate them into the movement of material flow, in which these stocks are created [19].

Strategies of material flow management and accounting in the supply chain at the enterprise are based on the management systems and consist of a set of measures for their creation and replenishment, operational planning of supply and organization of continuous monitoring. [16].

These systems of material flow accounting include a system of fixing orders; order frequency detection system; inventory accounting system; accounting system of supply; accounting system of production costs; accounting system of administrative and organizational costs [5]. These systems are fundamental in material flow accounting in supply chain management.

We have concluded that all the studied methods and algorithms of material flow accounting are fixated on the method of fixed order sizes and production, as well as on the basis of fixing all costs at all stages of the supply chain.

Inventory system of material flow accounting is based on the fact that all flows, aimed to replenish stocks, in the period of reducing supply to a certain level of standards, level of output, which is optimally designated [6]. All these values are calculated in such a way that when the indicators meet they provide a balanced supply chain demand.

Modern processes of automation and computerization on the basis of modern information technologies provide the accounting of material flow, production indicators and ensure effective material flow accounting in the supply chain management.

Information systems allow the collection, storage, accumulation, retrieval and transmission of data, which arise and are used in the process of material flow accounting [8], management and planning. Often, the collection, processing, and data accounting are modern information systems. In addition, they allow you to make links between

factors and indicators. At this level, there is also the identification of information and decision-making, and as a result, there is the determination of information needs; sifting unnecessary flow, taking into account the relevant flow, which complements each other. Table 1 systematizes the automated systems and programs to account for material flow for the efficient supply chain management.

**Table1.** Systematization of automated systems for material flow accounting

| | | |
|---|---|---|
| APM | The system, which helps to automate workstations. This is a complex system, which is designed in the image of a subsystem or application. It may also consist of Excel spreadsheets. The number of managers depends on measurements of the enterprise: one-two for small organizations and 3-5 for large ones. It is a kind of symbiosis of 1C and spreadsheets, which provide the implementation of management tasks. | [2] |
| ERP | This IP is implemented in the enterprise for accounting and resource management - enterprise resource planning. It allows operational, management and accounting of material flow. It also provides such functions as order planning, supply and inventory planning. In Russia, such programs as Axapta, Baan, JD Edwards, R/3 are the most commonly used. | [3] |
| BPM | A system that allows you to automate management processes, planning, and execution of tasks. This abbreviation stands for Business Performance Management. The main function of the system is to account for financial flows and financial management. In practice, such accounting programs as Planning, Comshare MPC, Oracle Financial Analyzer are often used. | [3] |
| OLAP | It is real-time data processing. The program is not focused on specific tasks, but it has reporting forms – analytical reports, business objects. In practice, such accounting programs as Business Objects, Essbase, Oracle Express, SAS and many others are often used. | [6] |
| Excel | It has the ability to create and download files with databases, reports, and tasks, taking into account the material flow. Excel allows you to do ABC analysis and a lot of other calculations, groupings, correlations, etc. There are also disadvantages of this type of accounting - tables and reports with a lot of data become unwieldy and complicate the process of supply chain management. | [6] |
| DSS | Decision Support System is used for accounting and management of inventory, purchases, movement of material flows. It is a kind of calculator for accounting and management of material flows. | [8] |
| BUY©ER | This system allows accounting for inventory, material flows, purchases, and making reports. Using this software, you can also predict demand, visualize the results to adjust. | [10] |
| Access material flow management | It is a system in the form of databases. Its purpose is to identify weaknesses in the material flows - the excess reserves, excess costs, and excess of the finished goods. | [8] |
| Logistics Expert | This program, introduced in 1C program, allows accounting of material flow movement among branches of the company | [20] |
| Dolphin | This software allows you to take into account the material flows necessary to implement the production and execution of the order according to the specified parameters: finance, logistics, and management. | [20] |
| SCM | This software is used for planning the production of finished goods: purchase/production/extraction of raw materials. It is a special 1C module for the standard configuration. It allows you to carry out accounting of material flows, purchases, payments, reporting and to create the visualization. | [18] |
| IMMEDIATELY | The System of Calculation of Automated Order with the level of cost accounting, demand, balances, and material flows. But this program has a drawback - there is no way to fix the periods of material flows, supply, and shipments. | [20] |
| ADR 1C | This module is for material flow accounting of supply chain with the help of which it is possible to predict, taking into account the trend and seasonality, and also to control prediction at each stage of the calculation. This software has flexible settings, which allows you to predict in accordance with the specified criteria and factors. It is easy and quick to install. This software has a disadvantage. You can only predict in the context of months. It is not suitable for companies that need daily prediction. | [20] |

The problems in material flow accounting, which are taking into account in the models and systems mentioned above, are based on the lack of a common methodology. Using statistical data does not allow you to create a model that will have the potential for universal application [18], because, in different industries and spheres of activity, material flows of the supply chain are recorded and accounted for in different ways. Using generalized statistics in combination with the universal statistics allows you to record resource consumption at the enterprise, providing a record of all the used means and costs, getting a generalized accounting model. At the same time, there are:

1. Limited discrimination of materials/raw material types: unbundling and matching materials/raw material types used in the supply chain in the created plugins of the database that allows you to measure the flows of material categories.
2. Limited permission for consumption: statistical data on traffic and international trade are used.
3. Limited understanding of the origin and purpose of material flows. Characteristics of the supply chain are made by combining the structures of products and materials, as well as the life cycle phase of the database. This makes it possible to identify economic activity related to the production of finished goods for consumption at the enterprise.
4. Lack of understanding the dynamics of the added stock. Stock dynamics is measured by combining the duration and throughput of database plugins that allows you to measure the potential of the enterprise each year [16].
5. Lack of knowledge about the extent of material flows. It is necessary to establish clear calculation methods for enterprises and to separate cross-flows from the material flows of a particular supply chain.

## 2. Materials and Methods

In this study, we have used methods of material flow accounting, the MFCA system regulated by ISO standard, through which the assessment of material losses in the supply chain in terms of money for the studied enterprise of Alliance Oil Company was carried out. Using this technique, the economic benefits of resource efficiency were determined. A model of material flow accounting in accordance with ISO 14051 was developed and proposed for Alliance Oil Company. However, the use of MFCA has shown that most of the costs are connected with material losses due to recycling products, waste, etc. Applying the methods of statistical groupings and analysis, a matrix of material flows for Alliance Oil Company was compiled.

## 3. Results

In order to achieve the tasks, we have developed a simple model of material flow accounting for Alliance Oil Company according to ISO 14051 standard (Figure 1). Material flows X, Y, Z are accounted for by Quantitative production cost accounting systems with their material inputs and outputs.

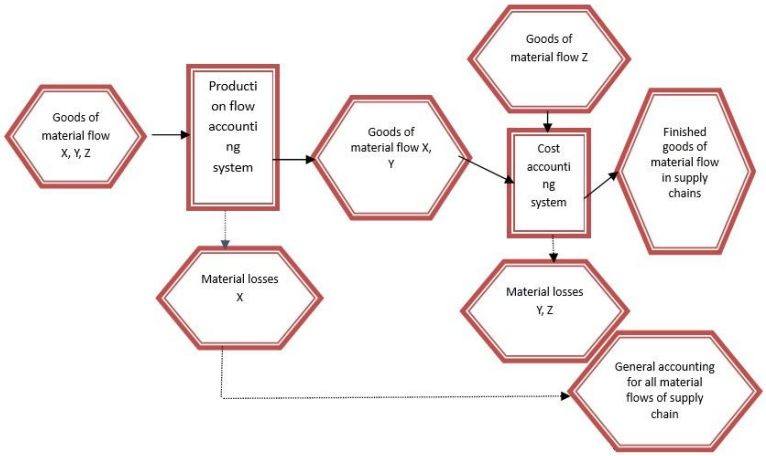


**Figure1**. The model of material flow accounting according to ISO 14051 standard (developed by the authors)

Alliance Oil Company is one of the largest oil companies in Russia. Using the MFCA system, a model of material flow accounting has been developed and proposed as a methodological basis. The material flow of oil refining has been the subject of analysis and research. It is found that the production of gasoline produces a significant amount of by-products and waste. Only by-products, which are about 36%, are recorded at normal accounting. However, the use of MFCA has shown that most of the costs are connected with material losses due to recycling products, waste, etc.

Distribution of material costs in material flows is based on the distribution among the finished goods and material losses in accordance with the volume costs. In the multi-stage production system of Alliance Oil Company, costs will be transferred to quality control. Other expenses are handled in the same way.

There are many potentials to reduce costs of Alliance Oil Company accounting material flow, and there is quite a lot of material flow accounting as a whole, pointed to their reduction, in particular, to avoid material losses.

Material flow accounting of Alliance Oil Company is primarily important to determine the depreciation

periods for investments in order to reduce the residual amount of the stocks. The distribution of material flows of the enterprise is made in accordance with the standard. For example, we have identified material costs in the amount of $6,500 (including weight and cost) in the cost matrix in Table 2. They are allocated among the product and material losses in accordance with the volume of costs, in other words, $5,500 on the product and $1,000 on material losses.

**Table2.** The matrix of material flow accounting of Alliance Oil Company in accordance with ISO 14051

| | **Production flow accounting system** | | | | | **Cost accounting system** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Material costs** | **Energy costs** | **System costs** | **Management costs** | **Total costs** | **Material costs** | **Energy costs** | **System costs** | **Management costs** | **Total costs** |
| Data of previous flows | | | | | | 6500 | 300 | 600 | | 8400 |
| Input data | 7500 | 300 | 700 | 200 | 8700 | 300 | 350 | 1300 | 500 | 2450 |
| Total in the accounting system | 7500 | 300 | 700 | 200 | 8700 | 6800 | 650 | 1900 | 500 | 9850 |
| Goods | 6200 | 250 | 600 | | 7050 | 4200 | 410 | 1630 | 500 | 6740 |
| Material losses | 700 | 70 | 100 | 200 | 1070 | 1000 | 215 | 755 | 500 | 2470 |
| Costs of material losses | | | | | | 2100 | 278 | 852 | 700 | 3930 |
| Total costs | | | | | | 6300 | 677 | 2482 | 700 | 10670 |

As a result of the development of this matrix, it is found that the total costs can be transferred to the category of material losses. In this case, they amounted to $3,930. $1,130 is energy and system costs of the refinery. These costs can be avoided if the material losses are identified and prevented. Unfortunately, the matrix of material flow shows that only $700 is directed to the system costs that also include the disposal costs, which are seen as the costs on material losses. At this enterprise, material flow and its total cost are quite different economic concepts, and its possibilities are opened to technical measures to reduce material losses. We have developed a model of usual material flow accounting of supply chain and costs for Alliance Oil Company and material flow accounting with minimization of losses during oil refining (Figure 2)

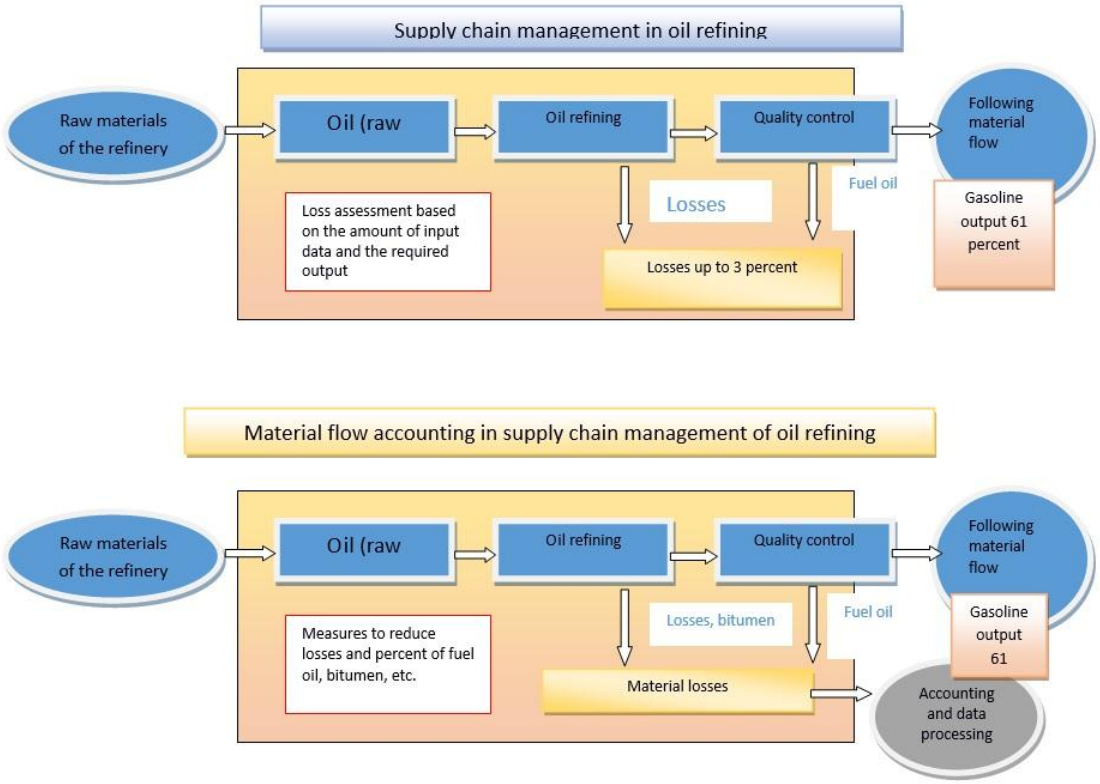


**Figure2**. Material flow accounting of Alliance Oil Company to assess and minimize losses
Source: (developed by the authors)

Applying MFCA material flow accounting of supply chain management flows, we have divided the costs among finished goods ("so-called positive" goods - gasoline, fuel oil) and waste. We believe that the different costs of the supply chain should be allocated to the processes and accounted for in the material flow according to the allocation. For each process, raw material costs, system costs, and management costs are recorded and allocated among the outputs. According to this method, 35 percent of the costs should be allocated to by-products and material losses.

## 4. Discussion

Many scientists do not find a common point of view on the advantage of MFCA methods of material flow accounting of supply chain [10, 17]. In terms of data accessibility, MFCA looks like a usual cost accounting, but it cannot provide all the required information. The usual cost accounting tracks cash flows of cost and interprets them as a cost of products, an entire company or subsystems. It focuses on the accuracy of cost for each product in each process and draws attention to the correlation among the cost of material flow production and periodic production costs, based on the accounting standards [8]. In contrast, there is also another view that first MFCA holds a record of all costs and then verifies the balances in each process [10]. Typically, supply chain managers know what the main inputs of each process are, and how many products are made from these resources. However, as a rule, they do not know how much material losses are generated in specific material flow.

A similar problem arises with respect to accounting for material flow costs for auxiliary materials and energy. At this stage, a detailed accounting of the data of each respective material flow process is provided by MFCA [13]. The specific weight of the inputs, outputs, materials losses and energy consumption are measured, and an extended inventory of material flow stocks is compiled for each process. This process is carried out step by step for the entire production line of the material flow production and supply/shipment of a specific product or production order. The result is a material flow model, shown in Figure 2. However, these flows are ultimately measured in monetary terms (cost matrix - Table 2).

Many Japanese companies consider MFCA as a new "kaizen". They usually collect most of the data by measuring the actual production situation and then visualize the current situation. To do this, we need the help of their functional departments such as Production Department, Engineering Department, Enterprise Management Department,

Cost Management Department, Department of Management of Production/Processing Environmental Impact, etc. [4]. However, in this case, the discrepancy in the accounting data will not be identified, but the real material loss cannot be calculated and accounted for in the material flow of the supply chain. Therefore, companies should examine the accuracy and relevance of their data and the importance of data collection and assessment of material flow costs [21].

Studies in different companies from different industries have shown that on average about 20 – 30 percent of material flow costs are associated with "negative" products or by-products. In today's economy and market situation, the majority of companies have already implemented numerous measures to reduce their material flows. Therefore, it is important that the MFCA method can reveal another previously described problem - the losses in the production processes of the material flow in supply chains [22].

An important aspect of the MFCA method is the analysis of supply chain and cost creation for a number of material flow processes. The advantage is that it provides information on the cost-loss in different stages of flows and makes it transparent. There is also a similarity with the methods of supply chain lifecycle accounting, which also contains important information in the material flow production and finished goods [23].

An important element of effective material flow accounting for the efficient supply chain management is that the data must be obtained from the accounting department and properly allocated over different material flows of the company. But there is a problem. Due to the low vertical depth of production at enterprises, many material flows are not allocated correctly. This means that the intermediate products are transferred to the B2B [23], and it is difficult to determine the final cost of finished goods. Although the buyer knows the cost of a product (calculated according to the generally accepted cost accounting), he/she has no information on material losses (in kg) and the cost of material damage (in $). To do this, he/she would be able to examine the internal costs of the manufacturer. Experience has shown that material losses extend to the entire material flow chain, and many measures must be applied at the beginning of the chain. This implies that companies cooperate with their suppliers and exchange data. This requires high confidence among the companies [23]. In Japan, these material flows are included in the chain of production, processing, pressing, heat treatment and many others. They are accounted for in the chain before the material flow is accounted for in the OEM, and then the final product is produced. However, in some countries, inter-company project relationships for the information exchange between the supplier and the customer are determined in material flow accounting. At the same time, in many Japanese projects, the information exchange was limited to material flows of supply chains by physical flows and technical problems, and the transmission of cost information was excluded. They aimed for the supplier and company would achieve savings and profit from them [23].

Thus, we have found that the application of MFCA determines losses, including the costs due to material losses. In many cases, the scale of the identified costs is greater than the expected company’s budget. We have identified the main types of typical losses of material flow accounting in MFCA:

1. The rise and rate of material loss process.
2. The reasons for the loss of material by processes (improper organization of the workflow, non-compliance with standards and norms, errors in statistics, etc.).
3. The purchase costs and material losses (main, auxiliary and operational materials).
4. The costs of recycling
5. The costs for the purchase of material losses sold to external recycling contractors.
6. System costs of material losses (labor, depreciation, fuel, utilities and other costs).
7. Material and system costs of available products, unfinished processes or materials that have been removed due to a change to a newer model or deterioration of the equipment [24, 25].

## 5. Conclusion

Market changes, lack of materials, environmental issues, and global competition are more important than ever, and they highlight that the efficient supply chain management and material flow accounting is a vital economic aspect of the world and each enterprise. In response, manufacturers and businesses are looking for alternative ways to increase productivity while reducing costs as an element of effective material flow accounting. MFCA can help organizations to achieve these goals through proper and timely material flow accounting for the efficient supply chain management.

We have found that the MFCA system is an information system of material flow accounting, which tracks all the raw materials, takes into account production processes and measures the outputs and costs. In addition to this method, ISO 14051 standard will provide the essential tools of material flow accounting and management to achieve sustainable development of the enterprise and high efficiency.

In the study, we have developed a model of material flow accounting for Alliance Oil Company, according to ISO 14051 with the division of the material flow into X, Y, Z and their accounting by Quantitative production cost accounting systems with material inputs and outputs. As a result of the development of this matrix, it is found that the total costs can be transferred to the category of material losses. In this case, they amounted to $3,930. $1,130 is energy and system costs of the refinery. These costs can be avoided if the material losses are identified and prevented.

Applying the MFCA system, we have developed a model of usual material flow accounting of supply chain and costs for Alliance Oil Company and material flow accounting with minimization of losses during oil refining, where the costs were divided among finished goods (gasoline, fuel oil) and waste (by-products).

Thus, it can be generally concluded that the different material flow costs of the supply chain should be allocated to the processes and accounted for in the material flow according to the allocation. It is found that according to this method, 35 percent of the costs should be allocated to by-products and material losses.

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